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Indian Standard

SPECIFICATION FOR HOLLOW METALLIC WAVEGUIDES

PART I GENERAL REQUIREMENTS AND TESTS

(First Revision)

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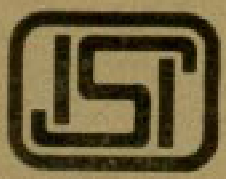

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SPECIFICATION FOR HOLLOW METALLIC WAVEGUIDES

PART I GENERAL REQUIREMENTS AND TESTS

(First Revision)

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Indian Standard

SPECIFICATION FOR HOLLOW METALLIC WAVEGUIDES

PART I GENERAL REQUIREMENTS AND TESTS

(First Revision)

0. FOREWORD

0.1 This Indian Standard (Part I) (First Revision) was adopted by the Indian Standards Institution on 22 November 1979, after the draft finalized by the Microwave Components and Accessories Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 This standard was first published in 1968 and was largely based on IEC Pub 153-1 (1964) 'Hollow metallic waveguides: Part I General requirements and measuring methods'. This standard is now being revised with a view to incorporating certain additional tests and the test schedule including the sequence of type, routine and acceptance tests.

0.3 This standard (Part I) deals with the general requirements and tests for hollow metallic tubing for use as wave guides in electronic and telecommunication equipment. The requirements including dimensions for various types of waveguides shall be covered by subsequent parts.

0.4 The object of establishing a series of standards on waveguides is to specify for hollow mettallic waveguides:

a) the details necessary to ensure compatibility and, as far as essential, interchangeability;

b) test methods; and

c) uniform requirements for the electrical and mechanical properties.

0.5 While preparing this standard assistance has been derived from the following:

IEC 153 - 1 (1964) Hollow metallic waveguides: Part I General requirements and measuring methods. International Electrotechnical Commission.

JSS 53000 General requirements for wave-guides, hollow. Directorate of Standardization, Ministry of Defence.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part I) prescribes general requirements and methods of test for hollow metallic tubing for use as waveguides in electronic and telecommunication equipment.

NOTE — Requirements for elliptical waveguides are under consideration.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply, in addition to those covered in IS : 1885 (Part XIII/Sec 2)-1967†.

2.1 Attenuation Constant — The loss per unit length of the waveguide at a specified frequency. The frequency shall be specified in the relevant detail specification.

2.2 Bow — The maximum deviation of the actual axis of the waveguide from a straight line of specified length connecting two points on that axis.

2.3 Twist — The rotation, over a specified length, of the cross section of the waveguides around the longitudinal axis.

2.4 Waveguide Twist

2.4.1 *Progressive* — A waveguide with a progressive rotation of the cross section about its line of centres.

2.4.2 *Binomial* — A device formed by introducing more than two successive abrupt rotations round the line of centres about a quarter of wavelength apart, each causing by itself a reflection approximately proportional to the coefficients of a binomial expansion.

NOTE — The expansion will be to a power ($n-1$) where 'n' is the number of abrupt rotations.

*Rules for rounding off numerical values (*revised*).

†Electrotechnical vocabulary: Part XIII Telecommunication transmission lines and waveguides, Sec 2 Microwave transmission lines and waveguides.

2.5 Surface Roughness — The average interior surface roughness of the waveguide.

2.6 Eccentricity — Half the difference between measured thickness of opposite walls. For determination of eccentricity, the thickness shall be measured where the most unfavourable result is obtained.

2.7 Ellipticity — It is defined as

$$E = \frac{D_{max} - D_{min}}{D_{nom}}$$

where

D_{max} = the largest measured inside dimension,
D_{min} = the smallest measured inside dimensions, and
D_{nom} = the nominal inside diameter.

NOTE — This term is applicable to circular waveguides only.

2.8 Rectangularity of Cross Section — The allowed deviation from rectangularity is defined by the requirement that the shape of the inside (outside) cross section shall be such that it is possible to inscribe the actual internal (external) cross section in the area between the specified maximum and minimum internal (external) rectangles.

2.9 Characteristic Impedance — The input impedance of an infinite waveguide length having similar cross section.

2.10 Cut-Off Frequency (of a Mode in a Waveguide) — That frequency below which a travelling wave in that mode cannot be maintained.

2.11 Cut-Off Frequency (of a Waveguide) — That frequency below which a travelling wave in the dominant mode cannot be maintained.

2.12 Reflection Coefficient (ρ) — It is the ratio of the complex number (vector) representing the phase and magnitude of the electric field of the backward-travelling wave to that representing the forward-travelling wave at a cross section of a waveguide. The term is also used to denote the modulus of this complex ratio.

2.13 Voltage Standing-Wave Ratio (V.S.W.R.) — The ratio of the amplitude of the transverse electric field at a cross section of maximum strength to the amplitude at the corresponding point in an adjacent cross section of minimum field strength.

$$\text{V.S.W.R} = \frac{1 + |\rho|}{1 - |\rho|}$$

2.14 Mode — Each of the possible fundamental configurations of the electromagnetic field of a travelling or stationary wave in a uniform waveguide. For a given mode, the field at any point is known if the behaviour at any single point, where the field is not zero, is known.

2.15 Dominant Mode (of a Waveguide) — The mode with the lowest cut-off frequency.

2.16 Transverse Electric and Magnetic Mode (TEM Mode) — A mode in which the longitudinal components of the electric and magnetic fields are everywhere zero.

NOTE — In this standard, the longitudinal component reffered is a component in the direction of propagation, while the transverse component is a component in a direction perpendicular to that of wave propagation.

2.17 Transverse Electric Mode (TE Mode or H Mode) — It is a mode in which longitudinal component of the electric field is everywhere zero and the longitudinal component of the magnetic field is not.

2.18 TE_{mn} Mode (H_{mn} Mode)

a) In a rectangular waveguide, the subscripts ' m ' and ' n ' denote the number of half period variations in the electric field parallel to the broad and narrow sides respectively of the waveguide.

b) In a circular waveguide, a mode which has ' m ' diametral planes in which the longitudinal component of the magnetic field is zero, and ' n ' cylindrical surfaces of non-zero radius (including the wall of the guide) at which the tangential component of the electric field is zero.

2.19 Transverse Magnetic Mode (TM Mode or E Mode) — A mode in which the longitudinal component of the magnetic field is everywhere zero and the longitudinal component of the electric field is not.

2.20 TM_{mn} Mode (E_{mn} Mode)

a) In a rectangular waveguide, the subscripts ' m ' and ' n ' denote the number of half period variations in the magnetic field parallel to the broad and narrow sides respectively of the guide.

b) In a circular waveguide, a mode which has ' m ' diametral planes and ' n ' cylindrical surfaces of non-zero radius (including the wall of the guide) at which the longitudinal component of the electric field is zero.

2.21 Precision Waveguide — A waveguide with closer dimensional tolerances than a standard waveguide. For example, whereas a waveguide of inner dimensions 165·10 mm × 82·55 mm has a tolerance of ± 0·127 mm, the precision waveguide of the same dimensions shall have a tolerance 0·051 mm. This is used in precision work such as in laboratory equipment.

2.22 Flexible Waveguide — A waveguide constructed to permit bending or twisting or both without appreciable change in the electrical properties.

2.23 Step Transition — A waveguide element whose cross section changes in size and possibly in shape, in steps. The number and size of steps depend on design frequency.

2.24 Taper Transition — A waveguide element whose cross section changes progressively in size and possibly in shape.

2.25 Bend — A waveguide with a smooth change in the direction of its line of centres.

2.25.1 E *Bend* — A waveguide bent so that throughout the length of the bend the direction of polarization (of the electric field of the dominant mode) is parallel to the plane defined by the line of centres.

2.25.2 H *Bend* — A waveguide bent so that throughout the length of the bend the direction of polarization (of the electric field of the dominant mode) is perpendicular to the plane defined by the line of centres.

2.26 Corner — A waveguide with an abrupt change in the direction of its line of centres.

2.26.1 *Binomial Corner* — A composite corner formed by more than two corners in succession about a quarter of wave length apart, each causing by itself a reflection coefficient approximately proportional in magnitude to the coefficients of a binomial expansions.

2.26.2 E *Corner* — A corner such that the directions of polarizations (of the electrical field) before and after the corner are parallel to the plane defined by the line of centres.

2.26.3 H *Corner* — A corner such that the directions of polarizations (of the electric field·) before and after the corner are perpendicular to the plane defined by the line of centres.

2.27 Stock Length — The standard straight length of a finished waveguide.

2.28 Wall Thickness — Half the difference between nominal outside and inside dimensions, measured at any cross section perpendicular to the longitudinal axis.

2.29 Type — Products having similar design features manufactured by the same techniques and falling within the manufacturer's usual range of ratings for these products.

NOTE 1 — Mounting accessories are ignored, provided they have no significant effect on the test results.

NOTE 2 — Ratings cover the combination of:

a) electrical ratings,
b) sizes, and
c) climatic category.

2.30 Type Tests — Tests carried out to prove conformity with the requirements of this standard. These are intended to prove the general qualities and design of a given type of waveguide.

2.31 Acceptance Tests — Tests carried out on samples selected from a lot for the purposes of the acceptance of the lot.

2.31.1 *Lot* — All waveguides of the same type, category and rating manufactured by the same factory during the same period, using the same process and materials.

2.32 Routine Tests — Tests carried out on each waveguide to check requirements which are likely to vary during production.

3. CLIMATIC CATEGORIES

3.1 For the purpose of climatic tests, the waveguides shall belong to one of the following two categories:

Severity	*Category 1*	*Category 2*
Dry heat	+ 100°C	+ 85°C
Cold	— 40°C	— 10°C
Rapid change of temperature	— 40°C to + 100°C	— 10°C to + 85°C

4. MATERIALS, CONSTRUCTION AND WORKMANSHIP

4.1 Material — The material shall be aluminium, aluminium alloy, copper, copper alloy, magnesium-base alloy, silver alloy, silver lined copper, or silver lined copper alloy as specified below.

4.1.1 *Aluminium* — Grade TIC conforming to IS : 738 - 1966*.

4.1.2 *Aluminium Alloy* — Grade HT 20 conforming to IS : 738 - 1966*.

4.1.3 *Copper* — Pure high conductivity electrolytic tough pitch (ETP) copper conformity to IS : 191 - 1967†.

NOTE — As an alternative material to this, oxygen free high conductivity copper and DHP — 1 conforming to IS : 191 - 1967†, may be permitted and this is recommended for use only where high conductivity copper would present manufacturing problems such as embrittlement during heat treatment.

4.1.4 *Brass 70/30* — Alloy No. 1 conforming to IS : 407 - 1966‡.

4.1.5 *Brass 90/10* — Under consideration.

4.1.6 *Magnesium* — Under consideration.

4.1.7 *Magnesium Alloy* — Under consideration.

4.1.8 *Silver* — Commercial standard silver having a nominal composition of 92·5 percent silver and 7·5 percent copper with maximum impurity of 0·1 percent.

4.1.9 *Lined* — To special orders only. Copper, brass and silver as specified above shall be used for lining.

4.2 Construction, Workmanship and Finish

4.2.1 The waveguide shall be manufactured and processed in a careful and workman like manner in accordance with good engineering practice.

4.2.2 The waveguide shall be free from defects of a nature that may interfere with all its applications. The waveguide shall be uniform in composition and wall thickness. These shall be smooth from end to end and free from internal and external mechanical imperfections, and shall have a clean, bright appearance in accordance with good commercial practice. In addition, the interior surface of the waveguide shall be free from burrs, die marks, chatter marks, dirt, grease, scales, splinters and oxides.

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*Specification for wrought aluminium and aluminium alloys, drawn tube (for general engineering purposes) (*revised*).

†Specification for copper (*second revision*).

‡Specification for brass tubes for general purposes (*second revision*).

5. ELECTRICAL RATINGS

5.1 The relevant specifications for waveguides shall specify the appropriate electrical ratings, such as frequency range for dominant mode, attenuation per unit length, and power handling capacity.

NOTE — The attenuation constant shall be calculated using the formulae given in **9.3.1**. The values of attenuation given in the relevant specification are for 100 percent copper. For other materials these values should be multiplied by $(\rho/\rho_0)^{1/2}$ where ρ_0 is the resistivity of copper which is equal to $1{\cdot}724 \times 10^{-8}$ ohm. metre and ρ is the resistivity of the material used. For guidance, multiplication factors for a few materials are given below:

$$\frac{0{\cdot}421\,[\,(f/f_c)^2 + 1\,]}{(f/f_c)^{1/2}\,[\,(f/f_c)^2 - 1\,]^{1/2}}$$

For other materials the figures quoted should be multiplied by:

Material	*Resistivity* Ohm.metre $\times 10^{-8}$	*Multiplied by*
Silver 100 percent	1·56	0·98
Copper (ETP)*	1·72	1·00
Silver ($7\frac{1}{2}$ percent copper)	1·80	1·06
Aluminium (100 percent)	2·83	1·30
Brass (90 percent copper)	3·90	1·55
Magnesium (100 percent)	4·60	1·68
Brass (70 percent copper)	6·50	2·00

6. DESIGNATION OF WAVEGUIDES

6.1 The waveguides shall be designated as follows:

a) A letter indicating the shape of the inside cross section of the waveguide:

R = Ordinary rectangular (in which the ratio of height to width is approximately 1 : 2),

M = Medium flat rectangular (in which the ratio of height to width is approximately 1 : 4),

*Pure high conductivity electrolytic tough pitch copper (ETP) conforming to IS : 191-1967 Specification for copper (*second revision*).

F = Flat rectangular (in which the ratio of height to width is substantially greater than 1 : 8),

C = Circular,

Q = Square,

E = Elliptical, and

ρ = Rectangular waveguides with circular outside cross section.

NOTE — For other types of waveguides this letter indication shall be in accordance with the relevant specification.

b) A number indicating or characterising the particular size of the waveguide. This number also indicates the frequency characteristic of the waveguide.

6.1.1 For example R 100 denotes an ordinary rectangular waveguide of internal dimensions (22·86 × 10·16 mm) with a centre frequency of approximately 10 GHz in the dominant mode with normal tolerances.

7. MARKING

7.1 Each waveguide shall be legibly and indelibly marked with the following information, in the order given below:

a) Type designation,

b) Manufacturer's name or trade-mark or both, and

c) Date code (*see* IS : 8186-1976*).

NOTE 1 — Additional marking, if any, shall be specified, so as not to cause confusion with other marking and shall be well separated from it.

NOTE 2 — Not more than 150 mm intervals shall be permitted from the end of one marking to the beginning of the next marking.

NOTE 3 — For smaller sizes where such marking is not practicable the marking shall be as prescribed in the relevant detail specification.

NOTE 4 — The method of marking shall not be detrimental to the performance of the waveguide.

7.1.1 The package of the waveguide shall contain information about the category and reference to relevant specification in addition to those specified in **7.1**.

*Marking codes for values and tolerances of resistors and capacitors.

7.2 The waveguides or their packings may also be marked with the ISI Certification Mark.

NOTE — The use of the ISI Certification Mark is governed by the provisions of the Indian Standards Institution (Certification Marks) Act and the Rules and Regulations made thereunder. The ISI Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well-defined system of inspection, testing and quality control which is devised and supervised by ISI and operated by the producer. ISI marked products are also continuously checked by ISI for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the ISI Certification Mark may be granted to manufacturers or processors may be obtained from the Indian Standards Institution.

8. PACKAGING

8.1 Waveguides shall be preserved and packed, so as to afford adequate protection against corrosion, deterioration and physical damage during transit. While packing, the lengths shall be kept separate by means of wood collar blocks properly secured to the box to prevent movements and damage while in transit.

8.2 The open ends of each waveguide shall be covered by a water vapour-proof barrier material or sealing plug so as to avoid corrosion or contamination in the interior portion of the waveguide tubing during storage and transit.

9. TESTS

9.1 Conditions for Tests

9.1.1 *General* — The tests shall be carried out on the waveguides as received from the manufacturer or supplier.

9.1.2 *Selection of Samples* — The samples for testing shall be so selected as to be representative of each category and the relevant type of waveguide.

9.1.3 *Atmospheric Conditions for Testing*

9.1.3.1 Unless otherwise specified, all tests shall be carried out under standard atmospheric conditions for testing as specified in IS : 9000 (Part I)-1977*.

9.1.3.2 Before measurements are made, the waveguide shall be stored at the measuring temperature for a time sufficient to allow the entire waveguide to reach this temperature.

*Basic environmental testing procedures for electronic and electrical items: Part I General.

9.1.3.3 When measurements are made at a temperature other than the specified temperature, the results shall, where necessary, be corrected to the specified temperature. The ambient temperature at which the measurements are made shall be stated in the test report.

9.2 Classification of Tests

9.2.1 *Type Tests* — The procedure for type approval shall be in accordance with IS : 2612-1965*.

9.2.1.1 *Number of samples* — Unless otherwise specified, the manufacturer shall submit 4 tubes, 1 metre long, in each material and of each size manufactured. The one metre length if cut from standard lengths, shall not be distorted or stressed.

9.2.1.2 *Grouping of samples* — The samples shall be grouped as indicated in Table 1.

9.2.1.3 *Sequence of type tests* — The sequence of type tests shall be in accordance with Table 1.

Group O tests shall be carried out immediately prior to commencement of tests on subsequent groups and the results shall be recorded. Each test shall be performed in the order listed and where measurements are required the results shall be recorded. Where tests are not applicable this will be indicated in the relevant specification.

TABLE 1 SCHEDULE OF TYPE TESTS

GROUP	TEST	CLAUSE REF	NUMBER OF SPECIMENS
(1)	(2)	(3)	(4)
0	Visual examination	9.4.1	4
	Dimensions	9.4.2	
	Bow	9.4.3	
	Twist	9.4.4	
	Squareness of cut	9.4.5	
1	Surface roughness	9.4.8	1
	Scratches	9.4.6	
2	Internal stresses	9.4.9	1
	Hardness	9.4.7	
3	Attenuation	9.3.1	1
4	Climatic tests	9.5	1

*Recommendation for type approval and sampling procedures for electronic components.

9.2.2 *Routine Tests* — Each waveguide shall be subjected to the following routine tests:

a) Visual examination (**9.4.1**), and

b) Dimensions inside cross section only (**9.4.2**).

9.2.3 *Acceptance Tests*

9.2.3.1 For the purpose of the acceptance of the lot, all the samples shall be subjected to the routine tests as given in **9.2.2.** Following this two groups of samples (Group A and B) shall be selected and the waveguides shall be subjected to the tests specified in Table 2 in the given order.

9.2.3.2 The schedule of acceptance test shall be in accordance with Table 2.

9.3 Electrical Tests

9.3.1 *Attenuation* — The attenuation in a suitable length of waveguide tube shall be measured at a frequency 1·5 times the cut-off frequency in H_{01} (TE_{01}) for rectangular waveguides and 1·2 times the cut-off frequency in the H_{01} (TE_{01}) mode for circular waveguides. The accuracy of the measurement shall be $\pm$ 10 percent of the required value in dB or 0·01dB whichever is more.

TABLE 2 SCHEDULE OF ACCEPTANCE TESTS

(*Clauses* 9.2.3.1 *and* 9.2.3.2)

GROUP	TEST	AQL (Percent Defective)	INSPECTION* LEVEL
(1)	(2)	(3)	(4)
Group 'A'	Bow Squareness of cut Twist	6·5%	I
Group 'B'			
Sub-group B1	Internal stresses Hardness Surface roughness Scratches	4%	III
Sub-group B2	Attenuation Climatic	4%	III

**See* IS : 2500 (Part I)-1973 Sampling inspection tables: Part I Inspection by attributes and by count of defects (*first revision*).

Unless otherwise specified, the attenuation shall not exceed 1·3 times the value calculated for the ideal surface and for the standard resistivity of the material concerned as specified below:

Calculations of attenuation shall be based on the following formulae which do not apply for thinly plated surfaces:

a) Rectangular weveguide [H_{01} (TE_{01}) mode]

$$\alpha = 2{\cdot}327\ 3 \left(\frac{\rho}{\rho_o}\right)^{\frac{1}{2}} \cdot \frac{1}{b \cdot \sqrt{a}} \cdot \frac{\left(\frac{f}{f_c}\right)^2 + \frac{2b}{a}}{\left(\frac{f}{f_c}\right)^{\frac{1}{2}} \cdot \left[\left(\frac{f}{f_c}\right)^2 - 1\right]^{\frac{1}{2}}} \text{ dB/m}$$

where

ρ = resistivity of inside non-magnetic wall metal,

ρ_o = resistivity of copper = $1{\cdot}724\ 1 \times 10^{-8}$ ohm.metre,

a = inside width in millimetres,

b = inside height in millimetres,

f_c = cut-off frequency for H_{01} (TE_{01}) mode = $\frac{149{\cdot}9}{a}$ GHz; and

f = frequency at which the attenuation is to be calculated.

b) Circular waveguides H_{11} (TE_{11}) mode

$$\alpha = 5{\cdot}040 \left(\frac{\rho}{\rho_o}\right)^{\frac{1}{2}} \cdot \frac{1}{D^{3/2}} \cdot \frac{1 + 0{\cdot}418\ 5 \left(\frac{f}{f_c}\right)^2}{\left(\frac{f}{f_c}\right)^{\frac{1}{2}} \cdot \left[\left(\frac{f}{f_c}\right)^2 - 1\right]^{\frac{1}{2}}} \text{ dB/m}$$

where

ρ = resistivity of inside non-magnetic wall metal,

ρ_o = resistivity of copper = $1{\cdot}724\ 1 \times 10^{-8}$ ohm.metre,

D = inner diameter in millimetres,

f_c = cut-off frequency for H_{11} (TE_{11}) mode = $\frac{175{\cdot}703}{D}$ GHz, and

f = frequency at which the attenuation is to be calculated.

9.4 Mechanical Tests

9.4.1 *Visual Examination* — The waveguides shall be visually examined and condition, design, workmanship, finish and markings shall be satisfactory. There shall be no burrs, cracks, pits or other irregularities of the surface. Both inner and outer surfaces shall have a clean bright appearance in accordance with current engineering practice.

9.4.2 *Dimensions* — The dimensions of the waveguides shall be checked with suitable gauges. The dimensions and the tolerance thereon shall be in accordance with the values given in the relevant specification.

NOTE — In principle, internal nominal dimensions shall be rounded off to the nearest 0·001 mm and external dimensions should be rounded off to the nearest 0·01 mm.

Unless otherwise specified, the following dimensions shall be given in the relevant specification:

a) Nominal dimensions of inside cross section,
b) Tolerances on inside dimensions,
c) Maximum radius of inside corner for rectangular waveguides,
d) Nominal wall thickness,
e) Maximum eccentricity,
f) Nominal dimensions of outside cross section.
g) Tolerance on outside dimensions,
h) Minimum and maximum radii of outside corner for rectangular waveguides,
j) Elliplicity for circular waveguides, and
k) Rectangularity of cross section.

9.4.2.1 *Ordinary rectangular waveguides*

a) *Inside dimension* — The ratio between height and width of the inside cross section is 1 : 2.

NOTE — For some sizes the ratio between height and width differs from this ratio. The tolerances both on width and height shall be given in the relevant specification.

If closer tolerances are necessary, a ratio of $\pm \frac{1}{1\,000}$ of inside nominal width is recommended. Inside corner radii shall be as given in relevant specification.

b) *Wall thickness* — The nominal wall thickness is defined as half the difference between nominal outside and inside dimensions. Its value shall be given in the relevant specification.

c) *Eccentricity* — The eccentricity is defined as half the difference between measured thickness of opposite walls. Unless otherwise specified, the eccentricity shall not exceed 10 percent of the nominal wall thickness. For the determination of the eccentricity, the thickness shall be measured where they give the most unfavourable results.

d) *Outside dimensions* — Nominal values of height and width shall be as given in the relevant specification.

NOTE — No outside dimensions may be specified for some of the largest sizes because a variety of manufacturing techniques are used.

The outside corner radius (r_2) shall be within the following limits:

$$r_{1\min} = 0{\cdot}5\ d$$

$$r_{2\max} = r_{2\min} + 0{\cdot}5 \text{ mm}.$$

where d = nominal wall thickness.

e) *Rectangularity of cross section* — The wall thickness and outside dimensions specified do not control the rectangularity of the cross section. The allowed deviation from rectangularity is defined by the requirement that the shape of the inside (outside) cross section shall be such that it is possible to inscribe the actual internal (external) cross section in the area between the specified maximum and minimum internal (external) rectangles. A suitable method for checking rectangularity is given in Appendix A.

9.4.2.2 *Flat rectangular waveguides*

a) *Inside dimensions* — The inside width of flat rectangular waveguides shall, except for special types, be equal to the inside width of corresponding sizes of ordinary rectangular waveguides. The ratio between height and width of the inside cross section is 1 : 8·33 but for the smaller sizes a fixed height is recommended. The tolerances both on height and width shall be as given in the relevant specification. Further 1 : 4 is recommended as an intermediate ratio between the ratios of 1 : 2 and 1 : 8·33.

NOTE — When it is necessary to deviate from a standard dimensions, it is recommended that the value be based on the geometrical mean between two consecutive standardized dimensions.

b) *Wall thickness* — The provisions of **9.4.2.1** shall apply.

c) *Eccentricity* — The provisions of **9.4.2.1** shall apply.

d) *Outside dimensions* — The tolerances both on width and height, shall be given in the relevant specification.

e) *Rectangularity of cross section* — The provisions of **9.4.2.1** shall apply.

9.4.2.3 *Circular waveguides*

a) *Inside dimensions*

i) *Diameter* — The nominal values for the inside dimensions and the tolerances thereon shall be as given in the relevant specification.

ii) *Ellipticity* — The ellipticity 'E' is defined as

$$E = \frac{D_{max} - D_{min}}{D_{nom}}$$

where

D_{nom} = the nominal inside diameter,

D_{max} = the largest measured inside dimensions, and

D_{min} = the smallest measured inside dimension.

The ellipticity shall not exceed the requirements given in the relevant specification.

b) *Wall thickness* — The provisions of **9.4.2.1** shall apply.

c) *Eccentricity* — The provisions of **9.4.2.1** shall apply.

d) *Outside dimensions* — The nominal values for outside dimensions and the tolerances thereon shall be as given in the relevant specification.

9.4.3 *Bow*

9.4.3.1 *Category I for component fabrication* — The bow is measured on the external surface of the waveguide. For a length of 10 times the internal width, the bow shall not exceed 10 times the specified tolerance on the internal width. For a length of 50 times the internal width, the external bow shall not exceed 40 times the specified tolerance on the internal width. For the determination of the bow, the waveguide shall be so positioned that gravity does not tend to affect the amount of bow.

NOTE 1 — For rectangular waveguides the bow shall be measured on both surfaces (edgewise and flatwise). For the purpose of tolerance, the smaller dimension (height) shall be considered for edgewise bow and larger dimension (width) for flatwise bow.

NOTE 2 — For circular waveguides, the bow shall be measured at two places perpendicular to each other.

9.4.3.2 *Category 2 for system applications*

a) *For rectangular waveguides* — The bow for any orientation shall not be more than 0·25 mm edgewise and 0·51 mm flatwise between any two points 600 mm apart on the concave external surface of the waveguide. The bow shall be uniformally distributed.

b) *For circular waveguides* — 0·25 mm between any two points 600 mm apart.

9.4.4 *Twist*

9.4.4.1 *Method of measurement* — The angle of twist of waveguides shall be measured as follows and as shown in Fig. 1:

a) The waveguide shall be placed on a flat, horizontal reference plane. Waveguides with noticeable flatwise bow shall be positioned with the waveguides surface on the side of convex curvature in contact with the reference plane.

b) One end of the waveguide surface shall be held in intimate contact with the reference plane by suitable means while the other end of the waveguide remains free.

c) Using an engraved, transparent protractor segment, determine the angle line on the protractor which coincides to the nearest degree with the surface of the waveguide, while one edge of the protractor segment contacts, or is kept parallel to the reference plane by means of parallel face blocks.

9.4.4.2 *Requirements*

a) *Category 1 for component fabrication* — The maximum twist along the longitudinal axis shall not exceed 1 degree per 300 mm of length on the face of the interior or exterior surface.

b) *Category 2 for system applications* — The rate of twist shall not exceed:

0·5 degree per metre for waveguides with an internal width equal to or larger than 100 mm; and

0·5 degree per length of waveguide equal to ten times the internal width when the latter is less than 100 mm.

Over a length equal to 50 times the internal width of the waveguide the accumulated twist shall not exceed 2 degree and the direction of twist should not be systematic in a batch of waveguides.

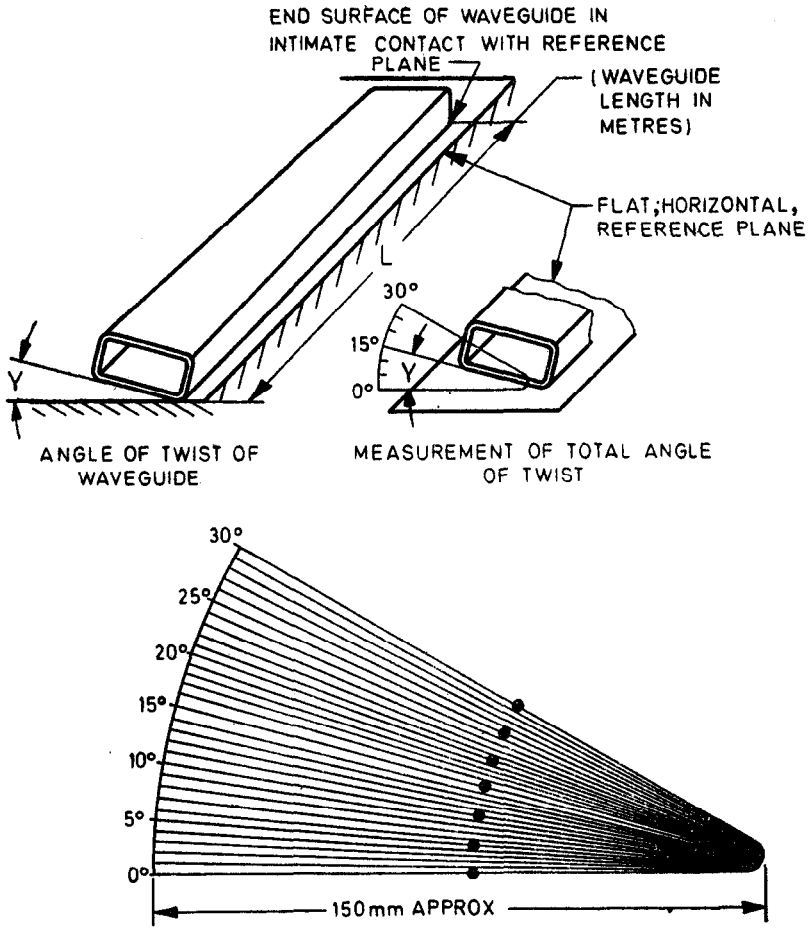

FIG. 1 METHOD OF DETERMINING TWIST

9.4.5 *Squareness of Cut (for Rectangular and Square Waveguides)* — The squareness of cut of the waveguide shall be measured. The departure from squareness of the end of any waveguide shall not exceed 0·25 mm for waveguides up to 16 mm maximum inside waveguide dimension inclusive and 0·4 mm per 25·0 mm for waveguides over 16 mm maximum inside waveguide dimension.

9.4.6 *Scratches* — Examination for scratches shall be 150 mm from each end and at the middle of the length. Scratches not more than 25·4 µm deep will be permitted in the longitudinal direction of waveguides with internal width/diameter of 15 mm or larger. For waveguides with smaller internal dimensions, the depth of scratches shall not exceed 0·12 percent of the width/diameter.

9.4.7 *Hardness* — The waveguide tube shall be tested for hardness at both ends around the periphery. The average of a minimum of six readings shall be within the tolerances stated below.

The waveguide shall comply with the following diamond pyramid hardness numbers, using a 10 kg load:

a) Copper	80 to 130
b) Brass 70/30	120 to 170
c) Brass 90/10	100 to 150
d) Silver	85 to 140
e) Aluminium	As specified in the contract
f) Lined	As for (a), (b) or (c) above as relevant
g) Copper electroformed	90 to 240
h) Magnesium	As specified in the contract

9.4.8 *Surface Roughness* — The surface roughness shall be measured as described in Appendix B. The average interior surface roughness of the waveguide shall not exceed the value shown in Table 3. Corner radius may not be included in the measurement.

TABLE 3 SURFACE ROUGHNESS TOLERANCES OF WAVEGUIDES

Specified Major Inner Dimension	Allowable Surface Roughness Maximum Arithmetic Average (A. A.)	
	Aluminium, Aluminium Alloy and Magnesium	Copper, Copper Alloy, Silver Lined Copper and Silver Lined Copper Alloy
(1)	(2)	(3)
mm	µm	µm
Up to 100	1·6	0·8
100 & over	3·2	1·6

9.4.9 *Internal Stresses* — The waveguide tube shall be cut by means of a saw. The cutting process shall be carefully controlled so as to avoid distortion arising from the cutting; and the use of a fine high-speed saw is recommended. After cutting, the cross-sectional dimensions of the tube shall still be within the specified tolerances.

9.5 Climatic Tests

9.5.1 *Dry Heat* — The waveguides shall be subjected to dry heat test in accordance with IS : 9000 (Part III/Sec 1) - 1977* at the maximum temperature of the temperature severity specified. Following measurements shall be made after recovery under standard atmospheric conditions:

a) *Visual Examination* — There shall be no mechanical deterioration.

b) Bow (*see* **9.4.3**).

c) Rectangularity of cross-section [*see* **9.4.2.1**(e)].

d) Twist (*see* **9.4.4**).

e) Ellipticity [*see* **9.4.2.3**(a)(ii)].

9.5.2 *Cold* — The waveguides shall be subjected to the cold test in accordance with IS : 9000 (Part II/Sec 1) - 1977† at the minimum temperature of the temperature severity specified. After recovery under standard atmospheric conditions, the measurements specified in **9.5.1** shall be made.

9.5.3 *Rapid Change of Temperature* — The waveguide shall be subjected to the procedure of IS : 9000 (Part XIV/Sec 1) - 1978‡ after recovery, under standard atmospheric conditions, measurements spectfied in **9.5.1** shall be made.

NOTE — This test may not be applicable for very long lengths of waveguide tubing.

*Basic environmental testing procedures for electronic and electrical items: Part III Dry heat test, Section 1 General.

†Basic environmental testing procedures for electronic and electrical items: Part II Cold test, Section 1 General.

‡Basic environmental testing procedures for electronic and electrical items: Part XIV Change of temperature, Section 1 Rapid change of temperature by two-chamber method.

APPENDIX A

[*Clause* 9.4.2.1(e)]

RECOMMENDED METHOD FOR CHECKING RECTANGULARITY

A-1. FOR INSIDE CROSS SECTION

A-1.1 Block, with the dimensions specified in **A-1.1.1**, shall pass through the waveguide without hindrance. In drawing the blocks through the waveguide, precaution shall be taken to keep it accurately normal to the waveguide axis.

A-1.1.1 For the dimensions of the block, the following shall apply:

a) Nominal dimensions of cross section	Nominal waveguide aperture size minus 1·1 times the tolerance
b) Tolerance on nominal dimensions of cross section	+ 0 — 0·1 times the tolerance on waveguide aperture
c) Perpendicularity of the sides	Not deviating by more than 3×10^{-4} radian
d) Length	0·2 times the internal width of the waveguide

A-2. FOR OUTSIDE CROSS SECTION

A-2.1 The outside cross section of the waveguide shall be such that it is possible to pass the waveguide through a gauge with an aperture of rectangular cross section.

A-2.1.1 For the dimensions of the aperture of the gauge the following shall apply:

a) Nominal dimensions of cross section	Nominal waveguide outside cross section plus 1·1 times the tolerance
b) Tolerance on nominal dimensions of cross section	— 0 + 0·1 times the tolerance on waveguide outside cross-section
c) Perpendicularity of the sides	Not deviating by more than 3×10^{-4} radian

APPENDIX B

(*Clause* 9.4.8)

SURFACE ROUGHNESS MEASUREMENT

B-1. The method for determining roughness height is described in Fig. 2. Υ is average deviation from the mean line, y is the ordinate of the curve of the profile, and l is the length over which the average is taken. A, B, C, D, etc, represent the deviation in micro-metres of the true surface from the mean surface at uniform intervals along the profile normal to the lay, or in the direction which gives the maximum value.

Then roughness height average:

$$y = \frac{1}{l}\int_{x=o}^{x=l} |y|\, dx$$

B-2. An approximation of the above may be obtained by adding Υ increments without regard to sign and dividing the sum by the number n of the increments taken.

$$\Upsilon = \frac{A+B+C+D.....}{n}$$

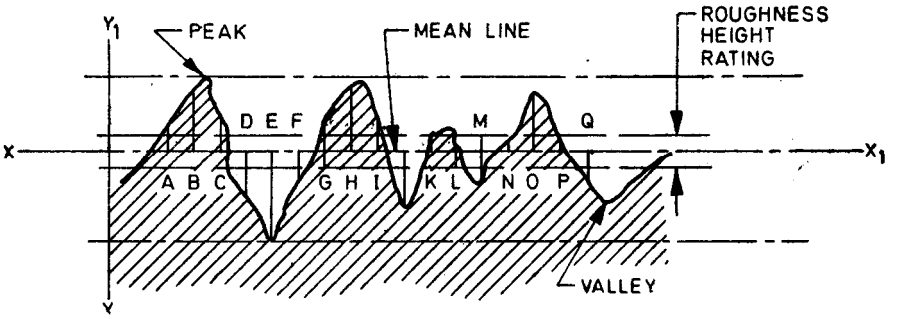

FIG. 2 TRUE SURFACE PROFILE

INDIAN STANDARDS
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MICROWAVE COMPONENTS AND ACCESSORIES

IS:

1885 (Part XIII/Sec 1)-1968 Electrotechnical vocabulary: Part XIII Telecommunication transmission lines and waveguides, Section 1 General transmission lines

1885 (Part XIII/Sec 2)-1967 Electrotechnical vocabulary: Part XIII Telecommunication transmission lines and waveguides, Section 2 Microwave transmission lines and waveguides

2032 (Part XIV)-1971 Graphical symbols used in electrotechnology: Part XIV Microwave technology

4493 (Part I)-1979 Hollow metallic waveguides: Part I General requirements and tests. (*first revision*)

INDIAN STANDARDS INSTITUTION

Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002

Telephones : 26 60 21, 27 01 31 **Telegrams : Manaksanstha**

Regional Offices:		Telephone
Western : Novelty Chambers, Grant Road	BOMBAY 400007	37 97 29
Eastern : 5 Chowringhee Approach	CALCUTTA 700072	27 50 90
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